ME 6101: Classical Thermodynamics

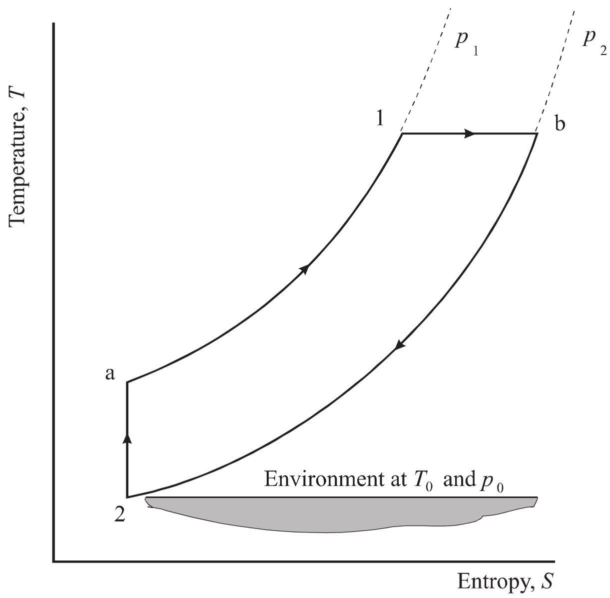
Term Paper 02[2023] **Submission Date: Before final exam.**

P-1: Evaluate the specific exergy of water vapour at 30 bar, 450°C if the surroundings are at 1 bar and 25°C. Evaluate the maximum useful work that can be obtained from this vapour if it is expanded to (i) 20 bar, 250°C; (ii) the dead state.

P-2: Air at 35°C and 100% RH is isothermally compressed to 1.0 MPa. Estimate the psychometric condition of the compressed air. If same atmospheric air is expanded to 0.01 MPa, estimate the psychometric condition. Try to solve the problem without using psychrometric chart.

P-3: Moist air at 28°C, 1 bar, and 50% relative humidity flows through a duct operating at steady state. The air is cooled at essentially constant pressure and exits at 20°C. Determine the heat transfer rate, in kJ per kg of dry air flowing, and the relative humidity at the exit. (Solve the problem without using psychrometric chart, and use the chart to validate your results)

P-4: The air follows the process 1-b-2 in Figure below, and transfers heat reversibly with the environment during an isobaric process from 1-b. Calculate the following specific work outputs for processes 1-b and b-2. Given that, state 1 is at 500 K and 2 bar.



(a) The work done by the system, dW_{sys};

(b) The work done against the surroundings, dW_{surr};

(c) The useful work done, dW_{use} and

(d) The work done by a reversible heat engine operating between the system and the surroundings, dW_R.

(e) Estimate the maxium work potntial of air at state 1.

P-5: Carbon monoxide and oxygen initially in a equimolar ratio are allowed to reach equilibrium at 1 atm and 3000K. Determine the composition of the equilibrium mixture.

P-6: One mole of carbon monoxide and 220 percent theoretical oxygen requirements, both initially at 25°C, undergo a reaction to form CO_2 in a steady-flow process at 1 atm. Neglecting dissociation of O_2, determine the final equilibrium composition and the final temperature if the process is adiabatic.

P-7: An adiabatic steam turbine operates with inlet conditions of 100 bars and 520°C and exit conditions of a saturated vapor at 3 bars. Kinetic- and potential-energy changes may be neglected and the environmental state is 300 K and 1 bar. Determine (a) the actual work output, (b) the reversible (maximum) work output, and (c) the availability of the exit stream, all answers in kJ/kg.

P-8: A gas turbine receives a mixture having the following molar analysis: 10% CO_2, 19% H_2O, 71% N_2 at 720 K, 0.35 MPa and a volumetric flow rate of 3.2 m^3/s. The mixture exits the turbine at 380 K, 0.11 MPa. For adiabatic operation with negligible kinetic and potential energy effects, determine the power developed at steady state, in kW.

P-9: An irreversible gas-turbine power plant operates between pressures of 1.0 and 6.4 bars with the compressor and turbine inlet temperatures of 22 and 807°C, respectively. Determine:

(a) the compressor and turbine work
(b) the heat supplied to the combustor
(c) the change in exergy across the three devices
(d) the irreversibility in all the three devices
(e) Effectiveness of the system

P-10: A simple steam power plant cycle generates steam in the boiler superheater at 140 bars and 560°C and condenses steam at 0.06 bar. The cooling water required in the condenser experiences a temperature rise from 18 to 28°C. The adiabatic efficiency of the turbine is 85% and that of the pump is 70%. Make suitable energy and exergy analyses for the cycle.

P-11: Saturated R-134a vapour enters the compressor at 0.2 MPa and leaves the condenser as saturated liquid at 0.8 MPa. Vapour leaves the irreversible compressor at 43.2°C. Estimate (a) COP, (b) Effectiveness of the cycle. Also, prepare energy & exergy balance sheet of the cycle.

P-12: Prepare the energy and exergy analyses of a combined cycle power plant using the data shown in the following page.

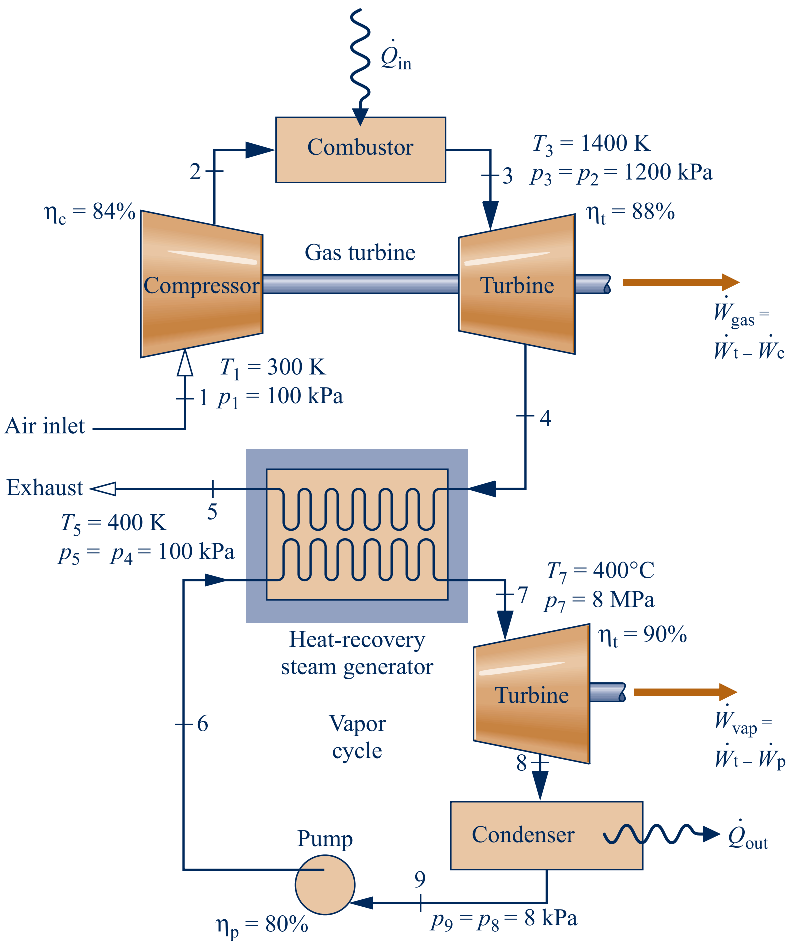
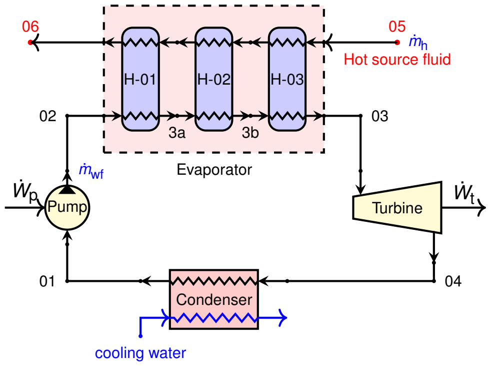


Fig. Combined cycle power plant.

P-13: Optimize the problem for R134a as the working fluid to get maximum thermal efficiency.



Parameter	Symbol	Value
Hot source		
Fluid [41]		Dry air
Mass flowrate	$\dot{m}_h$	1.0 kg/s
Inlet temperature	$T_{h,in}$	[100–300] °C
Outlet temperature [29]	$T_{h,out}$	60 °C
ORC system		
Condenser pressure [29]	P_{cond}	sat. at 30 °C
Evaporator saturated temperature	$T_{evap,sat}$	≤0.95 T_{cr}
Fluid quality in/out turbine [29]	X_{03}, X_{04}	≥0.90
Pump isentropic efficiency [29]	η_p	0.70
Turbine isentropic efficiency [29]	η_t	0.85
Pinch-point temperature difference [29]	ΔT_{pp}	10 °C
Environmental state		
Temperature	T_0	25 °C
Pressure	P_0	0.1 MPa